Publication number : 2001-209052

Date of publication of application : 03.08.2001

Int.Cl. G02F 1/1339 G02F 1/139

Application number : 2000-014545

Applicant : MATSUSHITA ELECTRIC IND CO LTD

Date of filing : 24.01.2000

Inventor : MOCHIZUKI HIDEAKI

LIQUID CRYSTAL DISPLAY DEVICE AND METHOD FOR MANUFACTURING THE SAME

[Abstract]

PROBLEM TO BE SOLVED: To provide a method for manufacturing a liquid crystal display device with high displaying precision irrespective of reduction of rubbing aligning treatment steps for the purpose of solving the problem resulting from the nonuniform rubbing aligning treatment.

SOLUTION: The method is provided with a step to form an alignment film 32 on the side of the first substrate 36 and subsequently to treat it with rubbing aligning, a step to form a spacer pattern 43 on the side of the second substrate 35, a step to form an alignment film 31 without the rubbing aligning treatment and a step to inject a liquid crystal 30 to which a chiral material is added to make the helical pitch p satisfy the relation p=(360/θ)×d (provided that θ expresses the twist angle of the liquid crystal molecules).

[Claims]

[Claim 1]

A liquid crystal display (LCD) device in which liquid crystals are filled between opposing first and second substrates and a cell thickness d between the first and second substrates is formed by a spacer pattern,

wherein an alignment layer that is rub-aligned is formed on the first substrate,

wherein the spacer pattern is formed to have the cell thickness d on the second substrate and an alignment layer that is not rub-aligned is formed on the second substrate, and

wherein a chiral material is added to the liquid crystals such that a spiral pitch p satisfies a relationship $p=(360/) \times d$, in which θ indicates a twist angle of molecules of the liquid crystals.

[Claim 2]

A method for manufacturing a liquid crystal display (LCD) device in which liquid crystals are filled between opposing first and second substrates and a cell thickness d between the first and second substrates is formed by a spacer pattern, the method comprising the steps of:

forming an alignment layer on the first substrate and rub-aligning the formed alignment layer;

forming a spacer pattern on the second substrate;

forming an alignment layer that is not subjected to rubbing alignment on the second substrate; and

injecting the liquid crystals to which a chiral material is added such that a spiral pitch p satisfies a relationship of p=(360/) × d, in which θ indicates a twist angle of molecules of the liquid crystals.

[Title of the Invention]

LIQUID CRYSTAL DISPLAY DEVICE AND METHOD FOR MANUFACTURING THE SAME

[Detailed Description of the Invention]

[Field of the Invention]

The present invention relates to a liquid crystal display (LCD) device and a method for manufacturing the same, in which a cell thickness is formed by a spacer pattern having a predetermined thickness.

[Description of the Prior Art]

As methods for driving a liquid crystal device (LCD) using the optical anisotropy of a liquid crystal, there are an active matrix driving method in which a liquid crystal panel is driven by an active device such as a thin film transistor (TFT) or a two terminal device and a simple matrix driving method in which striped transparent electrodes on opposing substrates are arranged orthogonally to each other and liquid crystal molecules in the cross area of the transparent electrodes are driven without using an active device. The active matrix driving method mainly employs a twisted nematic (TN) liquid crystal panel in which liquid crystal molecules are twisted 90° between opposing substrates. The simple matrix driving method usually employs a super twisted nematic (STN) liquid crystal panel in which liquid crystal molecules are twisted 180° - 270° between opposing substrates.

It has been known that a response speed, a contrast, and a viewing angle depend on the thickness of a liquid crystal layer (hereinafter, referred to as "a cell

thickness or a gap") in various liquid crystal panels. In particular, to obtain a high contrast, the cell thickness should be controlled finely. For example, in a liquid crystal panel driven by the active matrix driving method, a liquid crystal is filled between a first substrate and a second substrate, but the cell thickness is determined by a spacer. A method for manufacturing a liquid crystal panel generally involves coating an alignment layer onto opposing substrates, performing rubbing alignment on the alignment layer, coating a sealant onto one of the opposing substrates, coating a spacer onto the other substrate, and bonding the two substrates together. To inject a liquid crystal between opposing substrates, the liquid crystal may be injected after the substrates are bonded together or the substrates may be bonded together after the liquid crystal is dropped onto the substrate(s). Glass substrates are usually used as the opposing substrates. However, as the portability of information devices becomes more important, a display device using an organic high polymer material (plastic) is being put to practical use for the lightweightness of the display device. If a substrate is made of plastic, the uniformity of image quality is degraded.

Rod-shaped glass fibers or spherical plastic grains are used as a material of the spacer. The spacer is generally distributed in an arbitrary position of a substrate by scattering particles of the spacer from above the substrate. However, in such a spacer distributing method, the non-uniformity in spacer particle scattering or gap non-uniformity is generated due to the following causes. In other words, since the particles of the spacer are condensed by static electricity and a spacer distribution fluid used in scattering the particles of the spacer drops onto the substrate, distribution of the particles of the spacer on the substrate and the size of the particles of the spacer become non-uniform. In

addition, since there is an uneven portion due to a TFT or an electric line patterned on the substrate surface, gap non-uniformity is generated according to a position where the particles of the spacer are scattered even when the same-size particles are used.

To solve such a problem, there has been suggested a liquid crystal panel that forms a gap between substrates using an offset printing method. In this liquid crystal panel, unlike the conventional spacer distributing method, a gap is formed between substrates by directly forming a spacer pattern having a predetermined thickness in a predetermined position of a substrate without using particles of a spacer. In a liquid crystal panel driven by the active matrix driving method, a spacer pattern is formed to a cell thickness on the surface of a transparent electrode on one of substrates having a pair of transparent electrodes and an alignment layer that is subjected to rubbing alignment is formed on the substrate. In addition, an alignment layer is coated onto the other substrate where the spacer pattern is not formed and the alignment layer is then rubbing-aligned. Since the alignment layer on the surface of the substrate is rubbing-aligned such that a rubbing direction of the alignment layer is at 90°, a filled liquid crystal is aligned in the rubbing direction in an interface between the alignment layers due to anchoring force of the alignment layers and the molecules of the liquid crystal are twisted 90°. Moreover, since the liquid crystal is aligned along a single axis direction in the interface between the alignment layers, a uniform free tilt angle is generated.

[Problem(s) to be Solved by the Invention]

However, in a spacer pattern formation method, since rubbing alignment is performed after a spacer pattern is formed on an electrode, sufficient rubbing alignment cannot be performed on a shady portion of a step of the spacer pattern, causing a difficulty in obtaining uniform and flawless alignment of molecules of a liquid crystal. In other words, the liquid crystal is aligned along rubbing directions, but anchoring force of alignment layers with respect to the molecules of the liquid crystal does not affect a portion where the alignment layer is not rubbed, resulting in alignment defect. A plurality of areas having different alignment exists in an area where alignment is insufficiently performed. At a boundary between areas, discrimination where alignment of the molecules of the liquid crystal is discontinuous occurs and light leakage also occurs. In other words, the entire surface of an area where alignment is sufficiently performed darkens at an intermediate voltage level under the same alignment condition, but light leakage partially occurs or the non-uniformity of contrast where a dark portion and a light portion exist adjacent to each other occurs in an area where alignment is insufficiently performed.

To address such a rubbing non-uniformity problem, it is suggested that predetermined slopes are formed on side walls of the step of the spacer pattern (see Japanese Patent Laid-Open Publication No. Hei 06-273735). In this case, rubbing alignment can be performed on the shady portion of the step of the spacer pattern owing to the slopes, but an additional process of forming the slopes on the side walls of the spacer pattern is required and the angle of the slopes should be smaller than a predetermined angle. Thus, a high precision control is essential. Moreover, once the slopes are formed on the side walls of

the spacer pattern, an area where the spacer pattern contacts substrates decreases and a gap between the substrates may not be sufficiently secured.

In addition, if alignment is performed through rubbing, static electricity is generated due to friction and insulation may be destroyed in alignment layers or display defect may occur due to alignment defect in the alignment layers. When using rubbing alignment, since molecules of a liquid crystal are aligned in the same direction, viewing angle dependency occurs, in which observes view only a limited region of a display on a screen within a predetermined angle range.

Therefore, a first object of the present invention is to provide an LCD device which forms a cell thickness between substrates using a spacer pattern to solve a display non-uniformity problem caused by the non-uniformity of rubbing alignment and improve uniformity of an LCD. A second object of the present invention is to provide a method for manufacturing an LCD device, which reduces a process for rubbing alignment while providing a high-precision display to solve a problem caused by the non-uniformity of rubbing alignment.

[Means for Solving the Problem]

To solve the foregoing problems, the present invention provides a liquid crystal display (LCD) device in which a liquid crystal is filled between opposing first and second substrates and a cell thickness d between the first and second substrates is formed by a spacer pattern. An alignment layer that is rubbing-aligned is formed on the first substrate. The spacer pattern is formed to the cell thickness d on the second substrate and an alignment layer that is not rubbing-aligned is formed on the second substrate. A chiral material is added to the

liquid crystal such that a spiral pitch p satisfies a relationship p=(360/) × d (in which θ indicates a twist angle of molecules of the liquid crystal).

According to the present invention, by adding the chiral material to the liquid crystal such that the spiral pitch p satisfies the relationship p=(360/) × d, the molecules of the liquid crystal can be properly twisted without depending on anchoring force of the alignment layer of the second substrate. In addition, the alignment layer that is rubbing-aligned is formed on the first substrate where the spacer pattern is not formed and molecules of the liquid crystal can be aligned in a single axis direction in an interface of the alignment layer. Since the alignment layer that is not subjected to rubbing-alignment is formed on the second substrate where the spacer pattern is formed, rubbing non-uniformity caused by the non-uniformity of the thickness of the spacer pattern does not occur in the second substrate.

The present invention also provides a method for manufacturing a liquid crystal display (LCD) device in which a liquid crystal is filled between opposing first and second substrates and a cell thickness d between the first and second substrates is formed by a spacer pattern. The method includes the steps of forming an alignment layer on the first substrate and rubbing-aligning the formed alignment layer, forming a spacer pattern on the second substrate, forming an alignment layer that is not subjected to rubbing alignment on the second substrate, and injecting the liquid crystal to which a chiral material is added such that a spiral pitch p satisfies a relationship p=(360/) × d (in which θ indicates a twist angle of molecules of the liquid crystal).

According to the method, since the alignment layer is formed on the spacer pattern of the second substrate but the alignment layer is not rubbing-aligned, it

is not necessary to perform rubbing-alignment in the second substrate. Thus, rubbing non-uniformity does not occur. Since the rubbing-aligned alignment layer is formed on the first substrate where the spacer pattern is not formed, the molecules of the liquid crystal can be aligned in a single axis direction in an interface of the alignment layer. In addition, by injecting the liquid crystal to which the chiral material is added such that the spiral pitch p satisfies the relationship p=(360/) × d, the molecules of the liquid crystal can be properly twisted without rubbing-aligning the alignment layer of the second substrate.

[Embodiment of the Invention]

Hereinafter, embodiments of the present invention will be described in detail with reference to accompanying drawings.

(A configuration of an LCD device according to a first embodiment of the present invention)

In an LCD device according to the first embodiment of the present invention, the present invention is applied to an LCD device driven by an active matrix driving method using a TFT. As shown In FIGS. 1 through 3, a TFT 42, a pixel electrode 34, and an alignment layer 32 are formed on a first substrate 36 and a spacer pattern 43 is formed on a counter electrode 31 on a second substrate 35. A liquid crystal 30 is filled between the first substrate 36 and the second substrate 35, and polarizers 37 and 38 are disposed in the outer sides of the first substrate 36 and the second substrate 35.

The first substrate 36 has a size of 253mm x 190mm. As shown in FIG. 2, the TFT 42, electrode wiring (not shown) of a source, a drain, and a gate of the TFT 42, and the pixel electrode 34 are arranged on the first substrate 36. The

pixel electrode 34 is a transparent electrode using inzium·tartar oxide (hereinafter, referred to as an ITO) thin film, and switching of an electric field in the pixel electrode 34 is controlled by the TFT 42 formed for each pixel. There are 600 pixel pitches of 300 micron in a row direction and 2400 pixel pitches of 100 micron in a column direction. The size of a space between pixels is 15 micron × 15 micron.

The alignment layer 32 uses optimer AL1254 from Japan Synthetic Rubber Co., Ltd. as polyimide. The alignment layer 32 comes to have a thickness of 50nm after being heated and dried at 200°C for 1 hour. Alignment is performed using conventional rotation rubbing. By performing rubbing alignment on the alignment layer 32, molecules of the liquid crystal 30 can be aligned along a single axis direction in an interface of the alignment layer 32. In addition, by aligning the molecules of the liquid crystal 30 along a single axis direction, a free tilt angle can be generated in a predetermined direction in the alignment layer 32.

The second substrate 35 has a size of 248mm × 187 mm, a non-patterned ITO 33 is formed on the entire surface of the second substrate 35. The spacer pattern 43 using block photosensitive polyimide material having a thickness of 5.1μm is formed on the ITO 33. The liquid crystal 30 is filled between the first substrate 36 and the second substrate 35, thus to form a gap (cell thickness d) between the first substrate 36 and the second substrate 35. Glass is used for the first substrate 36 and the second substrate 35.

As shown in FIG. 2, the spacer pattern 43 has a thickness of 5.1μm over the entire remaining area except for a portion corresponding to the pixel electrode 34. By forming the spacer pattern 43 in the form of a square except for a portion corresponding to the pixel electrode 34 to open only the portion corresponding to

the pixel electrode, it is possible to prevent the non-uniformity of luminance that may occur due to blocking of irradiated light by the spacer pattern 43. Since rubbing alignment is not performed, if a spacer is formed using a conventional spacer pattern, it is possible to accurately control the position of the spacer and constantly control the height of the spacer in consideration of an uneven portion on a substrate.

Black photosensitive polyimide is used as a material for the spacer pattern 43. It is desirable to use a black material in that the black material has the effect of a block matrix that prevents light leakage occurring in other areas than the pixel electrode 34. Light leakage or light blocking by the spacer does not occur, and thus contrast or transmissibility as a liquid crystal panel can be improved. The spacer pattern 43 may be formed using a combination of polyimide and polyurethane. However, the material for the spacer pattern 43 may be any material that is not reactive with the liquid crystal 30 or the alignment layer 32 and can form the cell thickness d between the first substrate 36 and the second substrate 35.

The spacer pattern 43 is not necessarily formed over the entire remaining area except for the portion corresponding to the pixel electrode 34, but may be formed in a portion of the entire remaining area except for the portion corresponding to the pixel electrode 34. However, it is more desirable to form the spacer pattern 43 over the entire remaining area than to form the spacer pattern 43 in a portion of the entire remaining area. This is because a gap between the first substrate 36 and the second substrate 35 can be more certainly formed and light leakage from other areas than the pixel electrode 34 can be prevented over a wider range by using a black resin material for the spacer pattern 43.

An alignment layer 31 is formed on the surface of the second substrate 35 on which the spacer pattern 43 is formed. The alignment layer 31 has a thickness of 20nm and is formed by coating a diluted solution (solid content 2%) of optimer AL1254 in which urethane resin MS-5510 (its glass transfer temperature Tg = 63°C from Mitsubishi Heavy Industries Ltd.) of 10% by weight is mixed. The alignment layer 31 is not rubbing-aligned to solve a rubbing non-uniformity problem caused by the thickness of the spacer pattern 43. In addition, once rubbing alignment is performed, static electricity is generated and thus isolation is destroyed in the alignment layer 31. However, according to the present invention, since rubbing alignment is not necessary, such an isolation destruction problem does not occur.

Polyurethane is included in the alignment layers 31 and 32 to rearrange molecules of the liquid crystal 30 in an alignment direction for the purpose of solving a display non-uniformity problem resulting from flowing alignment. In other words, since the alignment layer 31 is not rubbed, once the liquid crystal 30 is injected between the alignment layers 31 and 32, the molecules of the liquid crystal 30 are aligned on the surfaces of the alignment layers 31 and 32 in a direction the liquid crystal 30 flows after being injected. Such a phenomenon is called flowing alignment, causing display non-uniformity. To solve display non-uniformity, the molecules of the liquid crystal 30 which are flowing-aligned should be re-aligned along a single axis direction. However, once aligned, the molecules of the liquid crystal 30 are strongly attached to molecules of the alignment layers 31 and 32 in the interface between the alignment layers 31 and 32. Thus, the molecules of the liquid crystal 30 strongly attached to the molecules of the alignment layers 31 and 32 should be released, but it is effective to activate thermal motions of both the molecules of the alignment layers 31 and

32 and the molecules of the liquid crystal 30. Thermal motions of the molecules of the alignment layers 31 and 32 become active at a temperature higher than the glass transfer temperature of polyurethane. Thermal motions of the molecules of the liquid crystal 30 become active at a temperature higher than a nematic-isotropic transfer temperature of the liquid crystal 30. Thus, the alignment layers 31 and 32 including polyurethane are used and a liquid crystal panel is heated for a predetermined amount of time at a temperature higher than the glass transfer temperature of polyurethane and the nematic-isotropic transfer temperature after the first and second substrates 36 and 35 are bonded. Then, motions of the liquid crystal 30 and the alignment layers 31 and 32 become active in an interface between the liquid crystal and the alignment layers 31 and 32 and motions of the molecules of the liquid crystal 30 attached to molecules of the alignment layers 31 and 32 become active. Thereafter, once a temperature is dropped, in a state where the liquid crystal 30 is fixed on the alignment layer 32 that is rubbed in a controlled alignment direction, the molecules of the liquid crystal 30 are re-arranged and uniform alignment over the entire surface can be achieved. In addition, through such a process, a free tilt angle of the molecules of the liquid crystal 30 changes into an average free tilt angle over the entire surfaces of the first and second substrates 36 and 35. In particular, the alignment layer 31 is not rubbing-aligned on the second substrate 36 and a free tilt angle is easy to change because the molecules of the liquid crystal 30 may be easily scattered in the alignment direction in an interface of the alignment layer 3. Thus, such a process is useful (see Japanese Patent Laid-Open Publication No. Hei9-244030). Thus, polyurethane is included in the alignment layers 31 and 32 according to the first embodiment of the present invention.

The first and second substrates 36 and 35 are bonded by a sealant 51 and the liquid crystal 30 is injected between the first and second substrates 36 and 35. The sealant 51 is made of ultraviolet hardening resin in which a glass bead of 1% weight having a diameter of 5.1μm is mixed. The sealant 51 is coated in a rectangular form of 246mm × 185mm over a neighboring area of the second substrate 35 using a dispenser. In addition, the polarizers 37 and 38 that only pass a light vibrated in a single axis direction and irradiate a light on a display screen are installed on the first substrate 36 and the second substrate 35.

The liquid crystal 30 has a positive refractive index isotropy Δn and Δn is 0.98. A twist angle θ of the molecules of the liquid crystal 30 is 90°, and a mixed liquid crystal composition 30 in which a chiral liquid crystal is mixed to make a spiral pitch of the liquid crystal 30 equal to 20μm(p=(360/) × d) is used. In other words, a chiral material is added to the liquid crystal 30 such that the spiral pitch p satisfies a relationship p=(360/) × d. In the first embodiment of the present invention, the mixed liquid crystal composition 30 is made by adding CB-15 from BDH Company of 0.33% by weight to the liquid crystal. The molecules of the liquid crystal do not depend on liquid crystal anchoring force of the alignment layer 31 and are properly twisted. More specifically, when the liquid crystal is not mixed with a chiral liquid crystal, the molecules of the liquid crystal are properly twisted and thus the alignment layer 31 should be rubbed in a predetermined direction. However, in the present invention, since the mixed liquid crystal composition mixed with the chiral liquid crystal is used, the molecules of the liquid crystal are properly twisted without rubbing-aligning the alignment layer 31 of the first substrate 26.

At this time, the spacer pattern 43 is formed on the first substrate 36 and the alignment layer 31 that is not rubbing-aligned is formed on the first substrate 36. The alignment layer 32 that is rubbing-aligned may be formed on the second substrate 35. In this case, the alignment layer 31 is formed on the remaining area of the first substrate 36 except for an area where the pixel electrode 34 is formed. Thus, since the TFT 42 and electrode lines are formed on the second substrate 36, the alignment layers 31 and 32 are not affected by static electricity and a viewing angle dependency problem can be solved.

(Method for manufacturing an LCD device according to the first embodiment of the present invention)

Hereinafter, a method for manufacturing an LCD device according to the first embodiment of the present invention will be described.

As shown in FIG. 2, after the TFT 42, the electrode wiring, and the pixel electrode 34 are formed, the alignment layer 32 is printed and coated over the surface of the pixel electrode 34 to have a thickness of 50nm after being dried and is then heated and dried at 200°C for 1 hour. An alignment material of the alignment layer 32 is polyimide that is optimer AL1254 from Japan Synthetic Rubber Co., Ltd. After being dried, the alignment layer 32 is aligned through general rotation rubbing.

An ITO beta electrode 33 that is not patterned is formed on the entire surface of the second substrate 35, and the spacer pattern 43 is formed to have a thickness of 5.1μm using black photosensitive polyimide. The spacer pattern 43 is obtained by patterning a black resin layer. Ultraviolet rays are irradiated to the second substrate 35 using a mask in which only a portion corresponding to the pixel electrode 34 of FIG. 2 is opened and the second substrate 35 is then

developed. The spacer pattern 43 is formed in the form of a square in the remaining area except for a portion corresponding to the pixel electrode 34 by removing photosensitive polyimide that is not hardened. The form of the spacer pattern 43 is not limited to a square, but a gap may be formed between the first substrate 36 and the second substrate 35. In addition, it is preferable that the form of the spacer pattern 43 does not block an irradiated light by hiding the pixel electrode 23. Thus, unlike in Japanese Patent Laid-Open Publication No. Hei 6-273735, a process for forming predetermined slopes in side walls of the spacer pattern 43 is not required to prevent rubbing non-uniformity.

Next, a diluted solution (solid content 2%) of optimer AL1254 in which urethane resin MS-5510 (its glass transfer temperature Tg = 63°C from Mitsubishi Heavy Industries Ltd.) of 10% by weight is mixed is coated over the second substrate 35 and the alignment layer 31 having a thickness of 20nm is formed. The alignment layer 31 is not rubbing-aligned. Since the alignment layer 31 is not rubbing-aligned, conventional rubbing non-uniformity does not occur and a rubbing alignment process can be reduced. The sealant 51 is coated over a neighboring area of the second substrate 35 such that the width of sealing is 0.5 mm.

A twist angle θ of the molecules of the liquid crystal 30 is 90°. A chiral liquid crystal is mixed to make a spiral pitch of the liquid crystal 30 equal to 20μm(p=(360/) × d), thereby manufacturing the mixed liquid crystal composition 30 (in which θ indicates a twist angle of the molecules of the liquid crystal 30). In the first embodiment of the present invention, CB-15 of 0.33% by weight from BDH Company is added to the liquid crystal to compose the mixed liquid crystal composition 30. In addition, the liquid crystal has a positive refractive index

isotropy Δn and Δn is 0.98. Thereafter, a required amount of the mixed liquid crystal composition 30 is dropped on the second substrate 36 and the first substrate 36 and the second substrate 35 are bonded together in a decompression state (100 pascal). In the first embodiment of the present invention, since the spacer pattern 43 is formed over the remaining area except for a portion corresponding to the pixel electrode 34, the spacer pattern 43 is formed in the form of a square to space apart portions of the pixel electrode 34 as shown in FIG. 2. Thus, for example, according to a method in which a liquid crystal is injected from a liquid crystal injection port after the first substrate 36 and the second substrate 35 are bonded together, the liquid crystal 30 cannot be injected into pixel portions separated from the liquid crystal injection port by the spacer pattern 43. To inject the liquid crystal 30 uniformly on the pixel portions, the first substrate 36 and the second substrate 35 should be bonded together after the liquid crystal 30 is dropped on the second substrate 36 as in the first embodiment of the present invention. In this case, the spacer pattern 43 is formed in the form of a square to separate pixels, but the liquid crystal 30 can spread to each pixel without any gap by bonding the first substrate 36 and the second substrate 35 after the liquid crystal 30 is dropped. Moreover, unlike vacuum injection, non-uniformity does not occur in a neighboring area of the liquid crystal injection port. After the liquid crystal 30 is filled between the first substrate 36 and the second substrate 35, the circumference of the first substrate 36 and the second substrate 35 is sealed with ultraviolet hardening resin.

The present invention is not limited to above-described liquid crystal injection, but any method for injecting the liquid crystal 30 uniformly between the first substrate 36 and the second substrate 35 can be used. Thus, when there is

no portion that is separated by the spacer pattern 43 like when the spacer pattern 43 is formed in a partial area except for a portion corresponding to the pixel electrode 34, an area may be reserved for a general liquid crystal injection port, the first substrate 36 and the second substrate 35 may be bonded together, and then the liquid crystal 30 may be injected (vacuum injection).

The liquid crystal panel manufactured by the above-described process is heated and left at 120°C for 12 hours, thereby achieving superior alignment of the molecules of the mixed liquid crystal composition 30. Here, the alignment layers 31 and 32 are composed of polyimide resin including polyurethane as at least one element, and the liquid crystal panel is heated at a temperature higher than the glass transfer temperature Tg of polyurethane and the nematic-isotropic transfer glass temperature of the liquid crystal after the liquid crystal is attached to the first substrate 36 and the second substrate 35, so as to re-arrange the molecules of the liquid crystal along the alignment directions. Once the liquid crystal is injected between the alignment layer 31 that is not rubbed and the alignment layer 32, the molecules of the liquid crystal 30 are aligned on the surfaces of the alignment layers 31 and 32 in a direction the liquid crystal 30 flows after being injected (flowing alignment). To solve display non-uniformity, the molecules of the liquid crystal which are flowing-aligned should be re-aligned in a single axis direction. However, once aligned, the molecules of the liquid crystal are strongly attached to molecules of the alignment layers 31 and 32 in the interface between the alignment layers 31 and 32. To release the molecules of the liquid crystal, which are strongly attached to the alignment layers 31 and 32, it is effective to activate thermal motions of both the molecules of the alignment layers 31 and 32 and the molecules of the liquid crystal 30. Thermal motions of the molecules of

the alignment layers 31 and 32 become active at a temperature higher than the glass transfer temperature of polyurethane. Thermal motions of the molecules of the liquid crystal 30 become active at a temperature higher than a nematic-isotropic transfer temperature of the liquid crystal 30. Thus, the alignment layers 31 and 32 including polyurethane are used. Once the liquid crystal panel is heated for a predetermined amount of time at a temperature higher than the glass transfer temperature of polyurethane or the nematic-isotropic transfer temperature of the liquid crystal, motions of the molecules of the liquid crystal and the molecules of the alignment layers 31 and 32 become active in an interface between the liquid crystal and the alignment layers 31 and 32 and motions of the molecules of the liquid crystal attached to the alignment layers 31 and 32 become active. Once a temperature is dropped, in a state where the liquid crystal 30 is fixed on the alignment layer 32 that is rubbed in a controlled alignment direction, the molecules of the liquid crystal 30 are re-arranged and uniform alignment over the entire surface can be achieved. In addition, through such a process, a free tilt angle of the molecules of the liquid crystal 30 changes into an average free tilt angle over the entire surfaces of the first and second substrates 36 and 35 (see Japanese Patent Laid-Open Publication No. Hei 9-2440303).

Therefore, according to the present invention, since it is not necessary to rubbing-align the alignment layer on the substrate where the spacer pattern 43 is formed, display precision can be improved while reducing a process for rubbing alignment. In addition, unlike Japanese Patent Laid-Open Publication No. 6-273735, it is unnecessary to form a stepped portion (side wall) having a trapezoid form of the spacer pattern 43 at a predetermined angle for uniform rubbing alignment, rubbing non-uniformity can be solved with a simple process.

(Embodiment 1)

The following experiment is carried out using the TN (LCD) device. After a TFT-TN LCD module is completed by installing a driver LSI52 in the TN LCD device, a square wave electric signal of 60Hz is input to the TFT-TN LCD module, a diffused light is irradiated from the second substrate 36, and pixels are displayed to measure the characteristics of the pixels. As a result, a contrast ratio measured in a direction perpendicular to the surface of a substrate is a maximum of 100:1. Here, the contrast ratio means a ratio of a luminance value in a white area to a luminance value in a black area in the same display screen. As alignment is better, a luminance value in a block area is smaller, i.e., light shielding becomes better. As a result of observing a display area while a voltage for halftone display is being applied, uniform display is obtained over the entire display screen and luminance non-uniformity caused by rubbing non-uniformity does not occur around the spacer pattern 43.

(Comparative Example 1)

Comparative example 1 is a conventional LCD device that requires rubbing alignment. As shown in FIG. 4, an alignment layer 31 is rubbing-aligned in a direction perpendicular to a rubbing direction of an alignment layer 32. In addition, a liquid crystal is composed of a liquid crystal composition 30 aligned by anchoring force of molecules of the liquid crystal of the alignment layer 32 that is rubbing-aligned. However, to keep a twisted direction of molecules of the liquid crystal constant, a small amount (which satisfies P=16d) of chiral is added. In this comparative example, chiral of about 0.1% weight is added. Except for such conditions, this comparative example 1 is the same as Embodiment 1. An electric signal is input to the TFT-TN LCD module, a diffused light is irradiated

from a second substrate, and the entire pixels are displayed halftones. As a result, luminance is partially non-uniform. As a result of reflectively observing a dark area in screen display with a microscope, the alignment layer 31 on a substrate where the spacer pattern 43 is formed has many portions that are not rubbed around the spacer pattern 43. Molecules of the liquid crystal are not aligned in a single axis direction and free tilt angle is not generated in a specific direction, in the portions that are not rubbed.

When comparing Embodiment 1 and Comparative example 1, luminance non-uniformity occurs due to rubbing non-uniformity around the spacer pattern 43 in comparative example 1. Such luminance non-uniformity is also caused by using the conventional liquid crystal 30 that is not mixed with chiral. On the other hand, in Embodiment 1, luminance non-uniformity caused by the thickness of the spacer pattern 43 does not occur and superior display precision is obtained.

(A configuration of an LCD device according to a second embodiment of the present invention)

In this embodiment, as shown in FIGS. 4 and 5, the first substrate 63 and the second substrate 61 have the same sizes as those in the first embodiment, respectively. However, the first substrate 63 and the second substrate 61 are composed of polyetersulfon. A transparent column electrode 62 is placed on the surface of the second substrate 61. The transparent column electrode 62 has a width of 0.315mm and a pitch between the transparent column electrodes 62 is 0.33mm. A transparent row electrode 64 is placed on the surface of the first substrate 63. The transparent row electrode 64 has a width of 0.10mm and a pitch between the transparent row electrodes 64 is 0.11mm.

A nematic liquid crystal material 65 that is the same as in the first embodiment is filled between the first substrate 63 and the second substrate 61. A polyimide-type low-temperature heated alignment layer 66 having a thickness of 60nm is formed on the second substrate 61. After being printed and coated and heated at 140°C for 2 hours to be hardened, the alignment layer 66 is rubbing-aligned using a rubbing rayon fabric rolled around a roller. By rubbing-aligning the alignment layer 66, molecules of the liquid crystal can be arranged in a single axis direction in an interface of the alignment layer 66. In addition, since a spacer pattern 80 is not formed in the alignment layer 66, rubbing non-uniformity caused by the thickness of the spacer pattern 80 does not occur.

As shown in FIG. 5, a bank spacer pattern 80 having a height of 5.1 micron and a width of 20 micron is formed on the first substrate 63 to surround an area where the transparent column 62 and the transparent row electrode 64 cross each other. The spacer pattern 80 is made of acryl-group negative black register without being limited thereto as in the first embodiment. Like the first embodiment, a black material is used, the spacer pattern 80 is preferably formed in the remaining area except for the area where the transparent column electrode 62 and the transparent row electrode 64 cross each other, and the spacer pattern 80 may be formed on the second substrate 61.

An alignment layer 67 is formed on the first substrate 63 on which the spacer pattern 80 is formed. The alignment layer 67 has a thickness of 20nm and is formed by coating a diluted solution (solid content 2%) of a polyimide-type low-temperature heated alignment layer in which urethane resin MS-5510 (its glass transfer temperature Tg = 63°C from Mitsubishi Heavy Industries Ltd.) of 10% weight is mixed. In addition, the alignment layer 67 does not undergo alignment

such as rubbing alignment. Thus, according to the present invention, like the first embodiment, rubbing non-uniformity caused by the thickness of the spacer pattern 80 can be solved. The present invention can be applied to an alignment layer composed of any material without being limited to the above-described material. In addition, if a heating process is included in a manufacturing process to fit a free tilt angle, the alignment layers 66 and 67 should include polyurethane as in the first embodiment. Moreover, like the first embodiment, the first substrate 63 and the second substrate 61 are bonded together, the liquid crystal is filled between the first substrate 63 and the second substrate 61, and polarizers 72 and 70 are placed on the first substrate 63 and the second substrate 61.

(Embodiment 2)

The following experiment is carried out using the TN LCD device. Like the first embodiment, after the TFT-TN LCD module is completed by installing the driver LSI52 in the TN LCD device, the square wave electric signal of 60Hz is input to the TFT-TN LCD module, a diffused light is irradiated from the second substrate 61, and pixels are displayed to measure the characteristics of the pixels. As a result, uniform display is obtained over the entire display screen and luminance non-uniformity caused by rubbing non-uniformity does not occur around the spacer pattern 80. As such, it can be seen that the present invention can be applied when the first substrate 63 and the second substrate 61 are composed of organic high polymer materials.

(Third embodiment)

In this embodiment, the present invention is applied to a super twisted nematic (STN) liquid crystal panel driven by a simple matrix driving method. This embodiment is the same as the first embodiment and the second embodiment

except for retardation plates 70 and 71 and a mixed liquid crystal composition 65. The first substrate 63 and the second substrate 61 are composed of glass and have a thickness of 0.5mm. Transparent electrodes 64 and 64 are placed on the first substrate 63 and the second substrate 61, respectively.

The alignment layer 67 is formed on the surface of the first substrate 63. The alignment layer 67 is made of the polyimide alignment layer 66 (PSI-2104 from Japan Nitrogen Corporation) and is treated at 200°C for 2 hours. The alignment layer 67 comes to have a thickness of 60μm after being hardened. The surface of the alignment layer 67 is rubbing-aligned by a rubbing rayon fabric rolled around a roller. By rubbing-aligning the alignment layer 67 on the first substrate 63, molecules of the liquid crystal can be aligned in a single axis direction in an interface of the alignment layer 67. By arranging the molecules of the liquid crystal in a single axis direction, a uniform free tilt angle can be generated in the alignment layer 67. However, since the spacer pattern 80 is not formed in the alignment layer 67, rubbing non-uniformity caused by the thickness of the spacer pattern 80 does not occur.

The bank spacer pattern 80 having a height of 7 micron and a width of 20 micron is formed on the second substrate 61 to surround an area where the transparent column 62 and the transparent row electrode 64 cross each other. A material of and a method for manufacturing the spacer pattern 80 are the same as in the second embodiment. Like the second embodiment, the alignment layer 67 that is not rubbing-aligned is formed on the first substrate 63 on which the spacer pattern is formed. Thus, it is possible to address a rubbing non-uniformity problem caused by the thickness of the spacer pattern 80. In addition, if a heating process is included in a manufacturing process to fit a free tilt angle, the

alignment layers 66 and 67 should include polyurethane as in the first embodiment.

A liquid crystal 65 has a positive refractive index isotropy Δn and Δn is 0.122. A twist angle θ of the molecules of the liquid crystal 65 is 240°, and a mixed liquid crystal composition 30 in which a chiral liquid crystal is mixed to make a spiral pitch of the liquid crystal 65 equal to 10.5μm(p=(360/) × d) is used. In this embodiment of the present invention, the mixed liquid crystal composition 65 is made by adding CB-15 from BDH Company of 0.63% weight to the liquid crystal. In addition, considering improvement in the uniformity of an STN device and easiness to manufacture, it is preferable that a cell thickness d is large and is generally between 5 – 7μm. Thereafter, the molecules of the liquid crystal do not depend on liquid crystal anchoring force of the alignment layer that is not rubbing-aligned and are properly twisted like in the first and second embodiments. Polarizing plates that are the same as in the second embodiment are attached to the first substrate 63 and the second substrate 61. Retardation plates 69 and 71 are attached to the polarizing plates for optical compensation of the simple matrix liquid crystal panel.

(Embodiment 3)

The following experiment is carried out using an STN LCD device 4. Like Embodiment 1, after a PM(simple matrix)-STN LCD module is completed by installing the driver LSI52 in the STN LCD device 4, a square wave electric signal of 60Hz is input to the PM-STN LCD module, a diffused light is irradiated from the second substrate 63, and pixels are displayed to measure the characteristics of the pixels. As a result, uniform display is obtained over the entire display screen and luminance non-uniformity caused by rubbing non-uniformity does not occur

around the spacer pattern 80. Therefore, the present invention can also be applied to the STN LCD device 4.

The foregoing embodiments are applied to a liquid crystal panel driven by an active matrix driving method and an STN liquid crystal panel driven by a simple matrix driving method, but the present invention can also be applied to a diode-type(MIM) liquid crystal panel.

[Effects of the Invention]

Since an LCD device according to the present invention uses a spacer pattern, it is possible to accurately control the position of a spacer and constantly control the height of the spacer in consideration of an uneven portion on a substrate. In addition, since an alignment layer that is not rubbing-aligned is formed on a second substrate on which the spacer pattern is formed, rubbing non-uniformity does not occur on the second substrate. Therefore, unlike a conventional case where alignment layers that are rubbing-aligned on a pair of transparent electrode substrates are used, non-uniformity of rubbing-alignment (rubbing non-uniformity) caused by the thickness of a spacer pattern does not occur and an LCD device having high display precision can be obtained. Furthermore, since it is not necessary to use a spacer pattern in which predetermined slopes are formed in side walls unlike prior art, a gap between substrates can be securely formed while a portion that supports substrates is not narrowed down.

In a method for manufacturing an LCD device according to the present invention, since a rubbing alignment process is not necessary in a substrate on which a spacer pattern is formed, rubbing non-uniformity caused by the

thickness of a spacer pattern does not occur and an LCD device having high display precision can be obtained. Moreover, since it is unnecessary to use a spacer pattern in which predetermined slopes are formed in side walls unlike prior art, an LCD device having high display precision can be obtained through a simple process.

[Description of Drawings]

FIG. 1 is a schematic cross-sectional view of an LCD device according to a first embodiment of the present invention.

FIG. 2 is a plan view illustrating a state where a spacer pattern is formed according to the first embodiment of the present invention.

FIG. 3 is a plan view of an LCD module according to the first embodiment of the present invention.

FIG. 4 is a schematic perspective view of an LCD device according to a second embodiment of the present invention.

FIG. 5 is a cross-sectional view of the LCD device according to the second embodiment of the present invention.

FIG. 6 is a schematic perspective view of an LCD device according to a third embodiment of the present invention.

FIG. 7 is a cross-sectional view of the LCD device according to the third embodiment of the present invention.

[Explanation on Numerals]

30, 65: Liquid crystal (Mixed liquid crystal composition)

31: Alignment layer (on a Second substrate)

32: Alignment layer (on a First substrate)

33: Common electrode (on a Second substrate)

34: Pixel electrode (on a First substrate)

35, 61: Second substrate

36, 63: First substrate

37, 38: Polarizing plate

42: Transistor unit (TFT)

43, 80: Spacer pattern (Black resin layer)

51, 68: sealant

52: Driver LSI

62: Column electrode

64: Row electrode

66, 67: Alignment layer

69, 71: Retardation plate

70, 72: Polarizing plate